



## Removing hand form information specifically impairs emotion recognition for fearful and angry body stimuli

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Abstract:	<p>Emotion perception research has largely been dominated by work on facial expressions, but emotion is also strongly conveyed from the body. Research exploring emotion recognition from the body tends to refer to 'the body' as a whole entity. However, the body is made up of different components (hands, arms, trunk etc.), all of which could be differentially contributing to emotion recognition. We know that the hands can help to convey actions, and in particular are important for social communication through gestures, but we currently do not know to what extent the hands influence emotion recognition from the body. Here, 93 adults viewed static emotional body stimuli with either the hands, arms, or both components removed and completed a forced-choice emotion recognition task. Removing the hands significantly reduced recognition accuracy for fear and anger, but made no significant difference to the recognition of happiness and sadness. Removing the arms had no effect on emotion recognition accuracy compared to the full-body stimuli. These results suggest the hands may play a key role in the recognition of emotions from the body.</p>

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**Removing hand form information specifically impairs emotion  
recognition for fearful and angry body stimuli**

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# Abstract

Emotion perception research has largely been dominated by work on facial expressions, but emotion is also strongly conveyed from the body. Research exploring emotion recognition from the body tends to refer to ‘the body’ as a whole entity. However, the body is made up of different components (hands, arms, trunk etc.), all of which could be differentially contributing to emotion recognition. We know that the hands can help to convey actions, and in particular are important for social communication through gestures, but we currently do not know to what extent the hands influence emotion recognition from the body. Here, 93 adults viewed static emotional body stimuli with either the hands, arms, or both components removed and completed a forced-choice emotion recognition task. Removing the hands significantly reduced recognition accuracy for fear and anger, but made no significant difference to the recognition of happiness and sadness. Removing the arms had no effect on emotion recognition accuracy compared to the full-body stimuli. These results suggest the hands may play a key role in the recognition of emotions from the body.

**Keywords:** Emotion recognition, body perception, hands

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# Introduction

Emotions play a crucial role in human social communication. In the past two decades, perception of bodies and bodily expressions has entered the research agenda, joining the vast literature exploring emotion recognition from facial expressions or recognition of speech prosody. We already know that several ‘basic’ emotions (happiness, sadness, fear, disgust, anger) can be recognized from static and dynamic stimuli depicting body form and movement (Meijer 1989, Atkinson, Dittrich et al. 2004, Grèzes, Pichon et al. 2007, de Gelder, Van den Stock et al. 2010, de Gelder and Van den Stock 2011, Ross, Polson et al. 2012). Furthermore, as in face research, emotional body recognition has been shown to be context dependent (Kret and de Gelder 2010), shows a protracted developmental trajectory (Boone and Cunningham 1998, Lagerlof and Djerf 2009, Ross, Polson et al. 2012), and has regions of visual cortex specialized for its recognition and interpretation (Downing, Jiang et al. 2001, de Gelder, Snyder et al. 2004, Peelen, Atkinson et al. 2007, Kret, Pichon et al. 2011, Ross, de Gelder et al. 2014, Ross, de Gelder et al. 2019).

Arguably, work investigating emotional body language has sought to equate itself with face research, drawing on the same paradigms and treating ‘emotional expression’ as similar between the two modalities (de Gelder 2009, van de Riet, Grezes et al. 2009, de Gelder, Van den Stock et al. 2010). However, although emotion expression from both modalities may superficially portray the same affective signals, we typically associate facial expression with internal mental states and body expressions with the action a person is performing (de Gelder, Van den Stock et al. 2010). Therefore it is possible that expressions of emotion

conveyed by the face, and by the body, may trigger different recognition processes in the observer.

There are also fundamental differences in the composition of face and body stimuli, and differences in how the diagnostic features of face and body emotion recognition are studied. Research on emotion recognition from faces has long recognized the key role played by specific diagnostic features for different emotions (e.g. nose wrinkling in disgust, wide eyes in fear etc. (Ekman 1992, Gosselin and Schyns 2001, Smith, Cottrell et al. 2005, Wegrzyn, Vogt et al. 2017)), whereas body recognition research still tends to treat 'the body' as one single entity.

Despite this, there is some evidence for a similar component based model of emotion recognition from the body. From a neuroscientific point of view, evidence has shown that different body parts are processed in specific dissociable areas in the visual cortex with the extra-striate body area (EBA) showing a preference for individual body parts such as the hands and fingers, and the fusiform body area (FBA) showing a preference for larger body parts such as the torso and headless bodies (Taylor, Wiggett et al. 2007). Bracci, Ietswaart et al. (2010) showed a brain region within the IEBA that displayed a selective response to hands over other body parts. In addition, there are several studies showing dissociable hand areas in the visual cortex when viewing hands both with and without objects (Grosbras, Beaton et al. 2012, Orlov, Porat et al. 2014, Perini, Caramazza et al. 2014). This suggests that instead of referring to the 'body-selective areas' of the visual cortex, the system might be more nuanced than the name implies. Indeed, studies that refer to the 'body-selective areas' may be looking at areas of cortex selective to individual body components (e.g. hands,

arms) rather than ‘the body’ as a whole (Downing, Jiang et al. 2001, Peelen and Downing 2005, Ross, de Gelder et al. 2014, Ross, de Gelder et al. 2019).

More recently, Dael, Mortillaro et al. (2012) demonstrate evidence for a component based model of emotional body recognition using body actions and postures. They show that another person’s emotions or intended actions are determined not from the ‘body’ per se, but rather from an observer using various components of the body form and position for emotion identification (e.g. trunk lean/orientation, arms, hands and legs configurations, (also see (Wallbott 1998, Gross, Crane et al. 2012)). Interestingly, using principle component analysis, they demonstrated that the component that explained the most variability in their dataset of emotional body movements was the form and position of the arms and hands. This suggests the arms and hands might be key contributors to our recognition of emotion from the body. Despite this, there is currently very little research investigating the importance of the hands and arms in emotional body recognition.

We already know that hand and arm gestures are crucially important to the communication of actions, with hand gestures in particular shown to be a key component of non-verbal communication (Cartmill, Beilock et al. 2012, Kang and Tversky 2016) and a significant characteristic of emotion recognition (Wallbott 1998, Dael, Mortillaro et al. 2012). Hand gesture recognition research both in humans (Krauss, Chen et al. 1996, Goldin-Meadow 1999, Obermeier, Dolk et al. 2012) and using human-computer interfaces (Murthy and Jadon 2009, Wachs, Kölsch et al. 2011) has demonstrated the importance of decoding such cues for effective communication.

Handedness in gestures has also been shown to be linked to communicating aggressive or passive emotional states (Kipp and Martin 2009), while in sign language and other situations where no other communicative modality is available, the hands have been shown to be effective conduits of emotional information (Reilly, McIntire et al. 1992, Hietanen, Leppänen et al. 2004). Different hand forms have also been associated with different emotional prototypes (Shaver, Schwartz et al. 1987, Givens 2002, Lopez, Reschke et al. 2017) and the recognition of hand gestures has been shown to be affected by congruent and incongruent emotional faces (Vicario and Newman 2013). In the most explicit test to date of the importance of hand and arm information for emotional body recognition, Fridin, Barliya et al. (2009) showed that subjects spend more time looking at the hands and arms of angry and fearful static full-body images than they did for joyful and sad body images when distinguishing between these emotions. All of this evidence suggests that the hands and arms are a key component used to convey and recognize emotion from the body, but the extent to which their position or form influences emotion recognition in an observer is currently unknown.

Therefore, here we asked whether the hands and arms play a key role in emotion recognition from the body, and whether their role is influenced by the emotion being conveyed. Using a widely cited, validated and open-source stimulus set of static whole body expressions of emotion (de Gelder and Van den Stock 2011), this study explored whether removing the hands and arms from these expressions affects the emotion recognition accuracy of observers.

It was first hypothesized that across the four emotions tested here (Happiness, Sadness, Fear and Anger), removing the hands and arms would significantly reduce

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emotion recognition ability. Furthermore, following on from the Fridin, Barliya et al. (2009) eye-tracking findings that subjects looked longer at the hands in fearful and angry stimuli, these emotions were predicted to be the most affected by removing the hands.

For Peer Review



## Methods

### Participants

Ninety-three undergraduate participants from Durham University (68 females, mean age = 19.5 years,  $SD = 1.0$  years) completed the study for course credits and provided written informed consent. All participants had normal or corrected-to-normal vision. Participants volunteered to take part and the study was approved by the Psychology Department Ethics Advisory Sub-Committee at Durham University.

### Stimuli

Stimuli were taken from the Bodily Expressive Action Stimuli Test (BEAST) (de Gelder and Van den Stock 2011). This set consists of whole body expressions from 46 actors expressing 4 emotions. The actor's face is blurred out and the static images are desaturated. It was found that in some of these stimuli there was a blurring effect on the hands caused by a shadow cast onto the wall behind the actor. This made it impossible to isolate the hands in these particular stimuli and therefore these identities were not used in the current study.

From the remaining set, stimuli from 20 randomly selected actors (12 female, reflecting the female:male ratio of the original stimuli set) were used, each portraying Happiness, Sadness, Fear and Anger. Photo-editing software GNU Image Manipulation Program (GIMP) was then used to create 4 conditions: Full Body, unedited full body stimuli; No Arms, arms removed from the shoulder but hands remaining; No Hands, hands removed from the wrist; and No Hands/Arms,

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both arms and hands removed from the shoulder (Fig 1). This allowed the differentiation of position and form information as removing the hands eliminated form information while keeping positional information, and removing both components negated both form and positional information.

For Peer Review

**Full Body**



**No Arms**



**No Hands**



**No  
Hands/Arms**



**Happy**

**Sad**

**Fear**

**Anger**

**Fig 1. Example of one actor portraying the four emotions (Happy, Sad, Fear and Anger) under the four stimuli conditions (Full Body, No Hands, No Arms and No Hands/Arms). Original Full Body stimuli taken from the BEAST stimuli set (de Gelder and Van den Stock, 2011).**

This gave us a total of 320 stimuli, 4 conditions for each of the 4 emotions portrayed by 20 different actors.

Procedure

Participants were presented with stimuli on a 15-inch monitor using MATLAB (Mathworks, Natick, MA) and Psychtoolbox (Brainard 1997). Participants sat 60cm away from the screen and stimuli were 4cm x 10cm, giving a visual angle of approximately 3.8° x 9.5°. They were instructed that they would see people portraying 4 different emotions, and their task was to select a key which best described the emotion on screen. Each participant completed 2 blocks of 96 trials, totaling 192 trials altogether. Stimuli were selected randomly from the 320 available and balanced so that each subject saw 12 iterations of each of the 16-condition/emotion combinations (Full Body Happy, Full Body Sad, Full Body Fear, Full Body Anger, No Hands Happy, No Hands Sad etc.) totaling 192 trials.

A trial consisted of a fixation-cross presented in the centre of the screen for 2 seconds, followed by a stimulus. Due to the varying amounts of visual information in each of the stimuli, we decided to allow the stimuli presentation time to be subject led, rather than be set at an arbitrary length. Therefore the stimuli image remained on screen until the participant responded. Participants were asked to determine which emotion was being portrayed in each image, with a four alternative forced choice of Happy, Sad, Fearful and Angry. Response options were allocated to C,V,B & N on the keyboard. Participants were instructed to use their left middle and index for C & V and right index and middle for B & N. The

order was reversed for half of the participants. Following the participant's choice, the fixation-cross reappeared and the next trial began.

## Analyses

### Emotion Recognition Accuracy

To examine the role of the hands in emotion recognition from the body, we compared emotion recognition accuracy across four conditions. Percent correct responses were calculated for each condition for each participant and averaged across all participants to give an overall percent correct response measure. Mean percentage accuracies were entered into a 4 x 4 repeated measures ANOVA with the factors Emotion (Happy, Sad, Fearful, Angry) and Condition (Full Body, No Arms, No Hands, No Hands/Arms). Post-hoc analyses underwent Bonferroni correction.

### Confusion Matrices

We then computed confusion matrices on all answers to gauge whether removing the hands or arms caused ambiguity among stimuli. Fear and Anger for example have the arms in similar positions, so removing the hands may lead to classification confusion among these stimuli. The results of our matrices may also shed some light on the different roles played by the form or position of the hands and arms if participants show more confusion with a particular emotion once some crucial diagnostic element is removed. We calculated the frequency of every response alternative for every stimulus emotion/condition and constructed confusion matrices on the basis of this analysis. Bonferroni corrected paired t-tests were performed on the number of incorrect responses to investigate whether the

intended emotion was systematically confused with any specific non-target alternative emotions.

**Response Time Analysis**

We also computed the median response time (RT) of each correct answer and entered them into a 4x4 ANOVA. We present a full written explanation of the response time results in Supplementary Material (see S1 Supplementary Material).

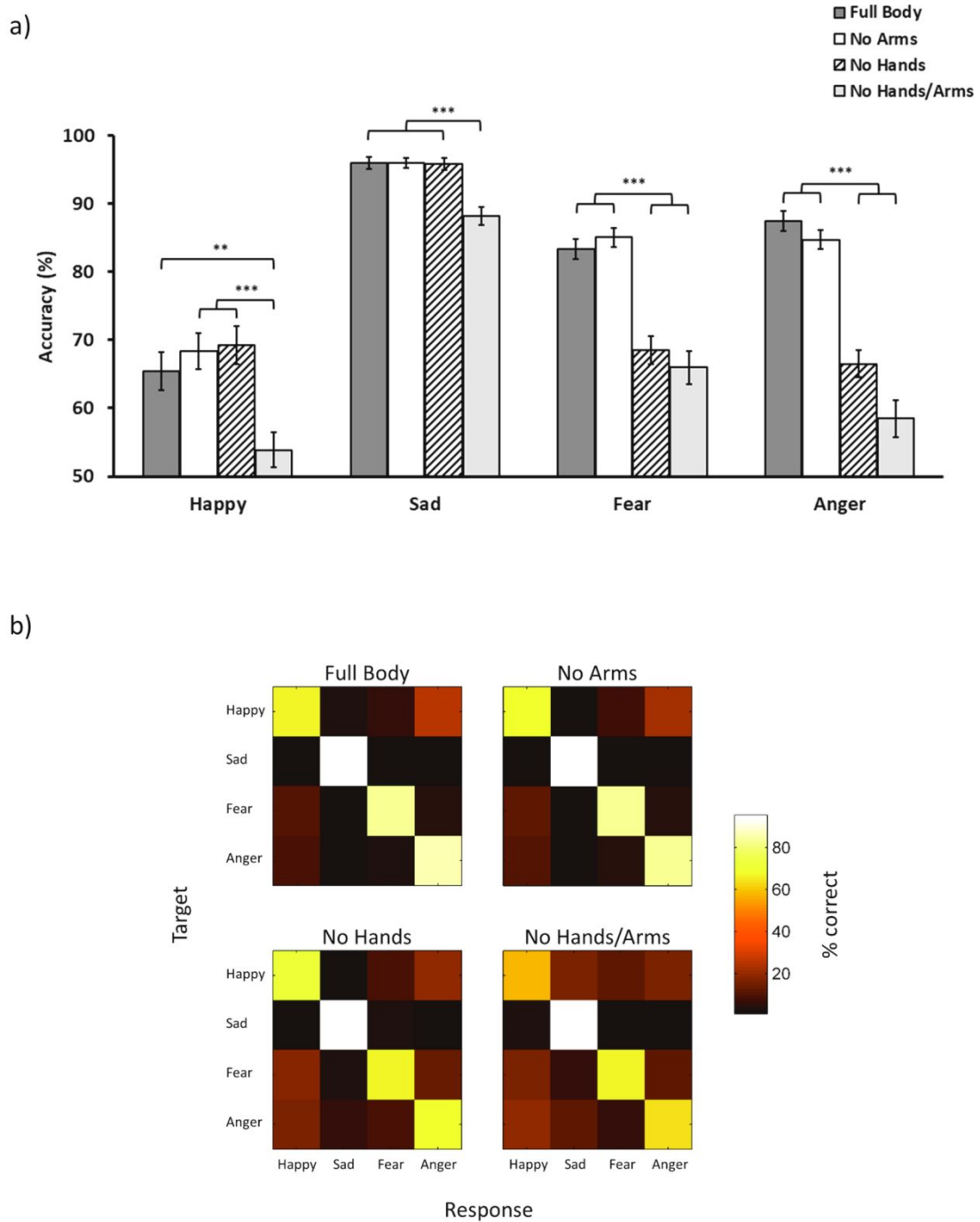
**Results**

**Gender Effects**

We first examined if there was an effect of either actor gender or participant gender, on emotion recognition. We performed a 2x2 mixed design ANOVA with actor gender as the within subjects variable and participant gender as the between subject variable. We found no main effect of actor gender ( $F(1,91)=1.06$ ,  $p=.306$ ,  $\eta^2p = .012$ ), no main effect of participant gender ( $F(1,91)=1.29$ ,  $p=.259$ ,  $\eta^2p = .014$ ) and no interaction  $F(1,91)=.187$ ,  $p=.666$ ,  $\eta^2p = .002$ ).

**Emotion Recognition Accuracy**

Mean accuracy results are presented below in Fig 2.



**Fig 2. a). Mean accuracy (%) of emotion recognition response for the four stimuli conditions, Full Body, No Arms, No Hands and No Hands/Arms at each emotion (Happy, Sad, Fear and Anger). Error bars represent SEM. Note that the y-axis is truncated to begin at 50%. \*\* =  $p < .005$ , \*\*\* =  $p < .001$ . b). Confusion matrices showing proportion of emotion classifications across all four body conditions. Colour-bars represent classification proportion as %.**

We found a main effect of Emotion (Happy:  $M=64.26$ ,  $SE=2.13$ ; Sad:  $M=93.99$ ,  $SE=0.66$ ; Fear:  $M=75.76$ ,  $SE=1.51$ ; Anger:  $M=74.28$ ,  $SE=1.26$ ;  $F(3,276)=78.05$ ,  $p<.001$ ,  $\eta^2_p = .459$ ). Bonferroni corrected pairwise comparisons revealed this main effect to be driven by significant differences between all emotions (all  $p<.001$ ) except Fear and Anger which showed no significant difference ( $p>.9$ ).

A main effect of Condition (Full Body:  $M=83.08$ ,  $SE=.96$ ; No Arms:  $M=83.53$ ,  $SE=.92$ ; No Hands:  $M=75.02$ ,  $SE=1.18$ ; No Hands/Arms:  $M=66.64$ ,  $SE=1.21$ ;  $F(3,276)=113.41$ ,  $p<.001$ ,  $\eta^2_p = .552$ ) was driven by significant differences between all conditions (all  $p<.001$ ) with the exception of Full Body and No Arms, which showed no significant difference in accuracy scores ( $p>.9$ ). Participants were most accurate in the Full Body condition and No Arm condition, with significantly reduced accuracy when either the hands, or hands and arms were removed, highlighting the key role played by the hands.

These main effects are qualified by a significant Emotion x Condition interaction ( $F(9,828)=15.56$ ,  $p<.001$ ,  $\eta^2_p = .145$ ). Post-hoc one-way ANOVAs of conditions across emotions found main effects of Condition under each Emotion (Happy,  $F(3,276)=13.86$ ,  $p<.001$ ,  $\eta^2_p = .131$ ; Sad,  $F(3,276)=23.85$ ,  $p<.001$ ,  $\eta^2_p = .206$ ; Fear,  $F(3,276)=59.1$ ,  $p<.001$ ,  $\eta^2_p = .391$ ; Anger,  $F(3,276)=62.63$ ,  $p<.001$ ,  $\eta^2_p = .405$ )

Bonferroni corrected pairwise comparisons showed that for Happiness, the No Hands/Arms condition ( $M=53.88$ ,  $SE=2.55$ ) led to significantly worse accuracy scores than Full Body ( $M=65.47$ ,  $SE=2.78$ ;  $p=.004$ ), No Hands ( $M=69.67$ ,  $SE=2.77$ ;  $p<.001$ ) and No Arms ( $M=68.40$ ,  $SE=2.68$ ;  $p<.001$ ) and there were no other significant differences between the other conditions (Full body and No Hands,  $p=.659$ ; Full Body and No Arms,  $p=.514$ ; No Hands and No Arms,  $p>.9$ ).



For Sadness, the No Hands/Arms condition ( $M=88.20$ ,  $SE=1.27$ ) led to significantly lower accuracy scores compared to Full Body ( $M=96.00$ ,  $SE=.84$ ;  $p<.001$ ), No Arms ( $M=95.94$ ,  $SE=.72$ ;  $p<.001$ ) and No Hands ( $M=95.82$ ,  $SE=.88$ ;  $p<.001$ ). No other conditions differed significantly (all  $p>.9$ ).

For Fear, we found that the No Hands/Arms condition ( $M=66.01$ ,  $SE=2.42$ ) again led to worse emotion recognition accuracy compared to Full Body ( $M=83.43$ ,  $SE=1.47$ ;  $p<.001$ ) and No Arms ( $M=85.08$ ,  $SE=1.39$ ;  $p<.001$ ) but no significant difference in accuracy compared to No Hands ( $M=68.50$ ,  $SE=2.02$ ;  $p>.9$ ). Crucially, we also found that the No Hands condition led to significantly worse accuracy compared to the Full Body condition ( $p<.001$ ) and No Arms condition ( $p<.001$ ). No significant difference was found between Full Body and No Arms ( $p=.968$ ). Thus, no impairment was observed when the hands were left intact, irrespective of whether the arms were removed.

Similarly, for Anger, we found that No Hands/Arms ( $M=58.45$ ,  $SE=2.79$ ) led to significantly worse emotion recognition accuracy compared to Full Body ( $M=87.46$ ,  $SE=1.52$ ;  $p<.001$ ) and No Arms ( $M=84.71$ ,  $SE=1.37$ ;  $p<.001$ ) but not compared to No Hands ( $M=66.49$ ,  $SE=1.97$ ;  $p=.054$ ). Interestingly, accuracy in the No Hands condition was again significantly worse than the Full Body ( $p<.001$ ) and No Arms ( $p<.001$ ) conditions. No significant difference was found between the Full Body and No Arms conditions ( $p=.528$ ).

### **Confusion Matrices**

We calculated the frequency of every response alternative for every stimulus emotion/condition and constructed confusion matrices on the basis of this analysis (see Fig 2b and Supplementary Table 1). This analysis is presented below.

1 Bonferroni corrected paired t-tests were performed on the number of incorrect  
2 responses to investigate whether the intended emotion was systematically  
3 confused with any specific non-target alternative emotions.  
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10 For Full Body stimuli, when the target was happiness we found that the stimuli  
11 were categorized more often as anger than fear ( $t(92)=6.20$ ,  $p<.001$ ) or sadness  
12 ( $t(92)=7.95$ ,  $p<.001$ ). None of the incorrect responses when the target was sadness  
13 were significantly different from each other. When fear was the target  
14 expression, happiness was found to be incorrectly identified significantly more  
15 often than sadness ( $t(92)=6.12$ ,  $p<.001$ ) and anger ( $t(92)=3.92$ ,  $p<.001$ ), and anger  
16 more often than sadness ( $t(92)=4.41$ ,  $p<.001$ ). When anger was the target  
17 emotion, we found that subjects identified it as happiness more often than  
18 sadness ( $t(92)=5.33$ ,  $p<.001$ ) and fear ( $t(92)=4.27$ ,  $p<.001$ ).  
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32 In the No Arms conditions, when the target happiness expressions were  
33 categorized more often as angry than fear ( $t(92)=4.87$ ,  $p<.001$ ) or sadness  
34 ( $t(92)=7.96$ ,  $p<.001$ ), as more often as fear than sadness ( $t(92)=4.86$ ,  $p<.001$ ).  
35 None of the incorrect responses when the target was sadness were significantly  
36 different from each other. When fear was the target expression, happiness was  
37 found to be incorrectly identified significantly more often than sadness  
38 ( $t(92)=5.88$ ,  $p<.001$ ) or anger ( $t(92)=4.24$ ,  $p<.001$ ), and anger more often than  
39 sadness ( $t(92)=4.63$ ,  $p<.001$ ). With anger as the target expression, happiness was  
40 incorrectly identified more often than both sadness ( $t(92)=5.72$ ,  $p<.001$ ) and fear  
41 ( $t(92)=4.09$ ,  $p<.001$ ), while fear was also incorrectly identified more often than  
42 sadness ( $t(92)=2.81$ ,  $p<.01$ ).  
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In the No Hands conditions, for target happy expressions, subjects categorized  
them as angry more often than fear ( $t(92)=4.14$ ,  $p<.001$ ) or sadness ( $t(92)=7.25$ ,

1 p<.001), and fear more often than sadness ( $t(92)=4.32$ ,  $p<.001$ ). When the target  
2 was sadness, subjects incorrectly categorized the stimuli as fear significantly more  
3 often than happiness ( $t(92)=2.01$ ,  $p<.05$ ). When fear was the target expression,  
4 happiness and anger was found to be incorrectly identified significantly more  
5 often than sadness ( $t(92)=7.41$ ,  $p<.001$  and  $t(92)=5.63$ ,  $p<.001$  respectively).  
6 When anger was the target expression, happiness was incorrectly identified  
7 significantly more often compared to sadness ( $t(92)=6.01$ ,  $p<.001$ ) and fear  
8 ( $t(92)=4.07$ ,  $p<.001$ ), while fear was incorrectly identified more often than  
9 sadness ( $t(92)=2.04$ ,  $p<.05$ ).

10 Finally in the No Hands/Arms condition, when the target was happiness we found  
11 the stimuli were incorrectly categorized as anger more often than fear  
12 ( $t(92)=2.19$ ,  $p<.05$ ). None of the incorrect responses when the target was sadness  
13 were significantly different from each other. When fear was the target  
14 expression, happiness and anger were both found to be incorrectly identified  
15 significantly more often than sadness ( $t(92)=4.0$ ,  $p<.001$  and  $t(92)=3.12$ ,  $p<.001$   
16 respectively). When anger was the target expression, happiness was incorrectly  
17 identified significantly more often compared to sadness ( $t(92)=2.56$ ,  $p<.05$ ) and  
18 fear ( $t(92)=5.25$ ,  $p<.001$ ), while sadness was incorrectly identified more often  
19 than fear ( $t(92)=3.67$ ,  $p<.001$ ).

# Discussion

The aim of this study was to explore the importance of the hands and arms for emotion recognition from the body. We compared emotion recognition accuracy across four emotions and manipulated the presence of the hands and arms in full body stimuli. It was hypothesized that across the four emotions (Happiness, Sadness, Fear and Anger), removing the hands and arms from whole-body static expressions would significantly reduce emotion recognition accuracy, particularly for angry and fearful stimuli. The results partially support this hypothesis.

We indeed found that removing the hands and arms significantly reduces emotion recognition accuracy compared to full body in all stimuli. Consequently, when participants have to rely only on the form and position of the trunk of the body and head there is a marked drop off in recognition accuracy. This suggests that hand/arm form and position (open arms in happiness, arms hanging in sadness, palm facing observer in fear, hands in fists in front of actor in anger) must therefore be informative as to the emotion being portrayed by the actor (Dael, Mortillaro et al. 2012). However, interestingly when the position of the hands was known, but the form information was removed (No Hand condition) it was found that in fearful and angry expressions, this significantly reduced emotion recognition accuracy compared to full body expressions, but made no significant difference to recognition accuracy in the happy and sad conditions.

These results compliment the findings of Fridin, Barliya et al. (2009) who found that participants looked longer at the hands of angry and fearful body stimuli (it should be noted that Fridin et al. used different stimuli, still images derived from video films in which semi-professional actors freely portrayed body postures

expressing four basic emotions). The form of the hands therefore appear to have a greater relative importance in the recognition of some emotions compared with others. Arguably, these threat-based emotions (anger and fear) are those that require an adaptive response from the observer (Pichon, de Gelder et al. 2008). When confronted with a happy or sad individual, an observer does not necessarily have to perform an action, and may be more concerned about that person's mental state or inner feeling. However, when confronted with an angry or fearful individual, expression of these emotions directs attention to a person's 'action' and it is in the observer's best interest to locate the source of this emotional response and act accordingly (de Gelder, Snyder et al. 2004).

It is clear from these stimuli that certain emotions are associated with specific hand forms (closed fist in anger and open forward facing palm in fear). It could be argued that in these cases, this form information relates to the functional action of the hands in these emotional states (using fists as weapons in anger, or flat hands as shields in fear), rather than the hands themselves conveying any explicit emotional information (Dael, Mortillaro et al. 2012, Lopez, Reschke et al. 2017). So whereas in face research, the diagnostic features may provide an observer with information regarding some inner emotional state of the expresser, in body research, emotion recognition may be achieved first through determining action or agency, and then using this to infer an inner emotional state (de Gelder 2009, de Gelder, Van den Stock et al. 2010). Dael, Mortillaro et al. (2012) demonstrated that the position and form of the arms and hands might be key contributors to our recognition of emotion from the body, and indeed it appears here that the form of the hands are more important for emotion recognition from body stimuli in which the hands are being 'used' for something.

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Further supporting evidence for this assertion comes from the point-light display (PLD) literature. Atkinson et al.'s (2004) seminal emotional body recognition study created two simultaneously captured sets of stimuli in which actors portraying 5 emotions (happiness, sadness, fear, anger and disgust) in full-light (FL) and PLD. The very nature of PLD means that the hand position information is represented but the hand form information is not. They found that between the FL and PLD stimuli, subjects were worse at recognizing disgust, fear and anger in PLD but showed no recognition difference across conditions for happiness and sadness. This result could be explained by the lack of hand form information in those three emotional PLD stimuli and mirrors our findings here (it should be noted that in disgust stimuli, the hands were being used to hold the nose/push things away; i.e. were being used for an action). Thus, when the ability to determine the action being performed by the hands in these stimuli (and in our current stimuli) was lost, emotion recognition performance decreased.

However, one possible alternative explanation for this recognition difference across emotions could simply be due to the configuration of the stimuli themselves within this stimuli set. In our happy and sad stimuli, the arms tend to be outstretched or hanging down respectively. Thus one does not need to use the hands for discriminating between these stimuli. In the fearful and angry stimuli, the configuration of the arms and hands are quite similar (out and in front of the body). So in these cases one may have to use the hands as a diagnostic feature in order to discriminate these stimuli. This is also true of the Fridin, Barliya et al. (2009) eye-tracking study in which participants looked longer at the hands of fearful and angry stimuli. However, if this was the explanation for our current results, one would expect fearful stimuli to be confused more with angry stimuli and vice versa. Instead, in our misclassification analysis we find no clear evidence

of the No Hand fearful condition being misclassified as anger any more than it was for happiness. Furthermore, in the No Hand angry condition subjects actually misclassified the stimuli as happiness significantly more than they did fear.

We found that the response time data complements the accuracy data, suggesting that removing information such as the hands in fear and anger leads to a longer time needed to make an accurate determination as to the portrayed emotion. Similarly removing both the hands and arms leads to longer RTs in all emotions with the exception of sadness. However, in sadness one could argue that the sunken shoulders and bowed head are the main diagnostic cues for emotion recognition and the arms and hands a secondary cue (Fridin, Barliya et al. 2009). These results add further evidence to suggest that the form of the hands are differentially important to some emotions compared to others in this stimuli set, while the form and position of the hands and arms are important diagnostic cues for all of the bodily emotions portrayed in our stimuli.

The evidence presented here, suggests that the additional loss of the hand position information in the No Hands/Arms condition was more detrimental to the recognition of happiness and sadness, but the loss of the form information alone was enough to lessen accuracy in anger and fear. This raises interesting questions regarding which hand and arm cues (e.g. form and position) are involved in emotion recognition from the body. In face stimuli, the diagnostic features conform to first order relational configuration (eyes above a centrally placed nose, above a centrally placed mouth (Rhodes 1988)). In body stimuli, however, not only can the features be of a different form (e.g. closed fist in anger, open palm in fear), they can also be in different positions relative to the trunk of the body (de Gelder and Van den Stock 2011, Lopez, Reschke et al. 2017). These positional changes

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differentiate recognition between the two modalities, and this leads to the question of whether it may be the position or the form of the hands that is a more useful cue for emotion recognition. Given the dissociation seen in the present study when the hands are removed between anger and fear, and happiness and sadness, it could be expected that the position of the hands will also have a different level of influence on recognition across different emotions. Indeed, our finding of an additional negative impact on recognition accuracy in happiness and sadness when the hand positional information is removed in the No Hands/Arms condition supports this prediction.

One might also imagine that these results will be of interest to those working with populations for which facial emotion recognition is somewhat atypical. Recent work for instance has shown that individuals with high levels of social anxiety looked away from the face when determining emotion, but instead focused on the hands (Kret, Stekelenburg et al. 2017). Similarly, Brewer, Biotti et al. (2017) showed that individuals with ASD who show a reduced attention to faces could have a greater reliance on bodily cues for emotion recognition. We have also previously shown that children are adult-like in their ability to recognize emotions from the body by approximately 8 years of age (Ross, Polson et al. 2012). We currently have no data however on whether the hands are differentially more important for children to determine bodily emotional expressions compared to adults. One could perhaps imagine that due to their height and the hands of parents/carers being eye-height for children of that age, that the hands may well be a more important source of emotional information for a child. In these instances, understanding how one determines emotions from the hands when face information is unavailable is of the utmost importance.



1 It should be noted that these interpretations may be somewhat limited to the  
2 stimuli in this particular set. Indeed, one could imagine a situation in which  
3 happiness is portrayed not by arms open wide but by a thumbs up or a high-five.  
4 Likewise fear could feasibly be portrayed by wrapping one's arms around the body  
5 and hunching up. In these scenarios one might expect the hands to be more  
6 important to the recognition of happiness than fear, the reverse of what we find  
7 with this stimuli set. However, in this case, this could also be due to the hands  
8 being 'used' for something in the happiness scenario (directly communicating) but  
9 not being used for anything in the fear (the arms are doing the 'wrapping'). This  
10 would make for an interesting direction for further study, in which stimuli are  
11 created in which *within* emotions, the actions of the hands vary much more than  
12 they do in standard body stimuli sets.

13 Furthermore, the stimuli in this data set display emotion in a quite similar manner  
14 across actors. This homogeneity in emotional poses across actors makes the  
15 generalization of findings to real life scenarios potentially problematic. We find  
16 that in this stimuli set, the hands have a greater importance for the recognition  
17 of fear and anger compared to happiness and sadness, but one could imagine with  
18 a wider range of diverse poses, there is the possibility that a more complex picture  
19 emerges. This homogeneity could partially be related to the fact that the emotions  
20 are 'posed' and not 'real' which is an issue to consider with controlled stimuli  
21 sets. In this instance the actors were presented with real life scenarios to react  
22 to in an attempt to increase the ecological validity of the expressions. However,  
23 a potential improvement could be to capture dynamic emotional reactions and  
24 take a still frame of the dynamic stimuli as done by Atkinson, Dittrich et al. (2004)  
25 and Fridin, Barliya et al. (2009). Furthermore, one could take several still frames,  
26 and thus create several different poses, from a single dynamic portrayal of an

emotion and explore the importance of the hands in this more varied stimuli set. Also, simply increasing the number of actors, and the number of scenarios presented to them, would increase the variety of emotional displays and in turn improve the generalizability. Reader and Holmes (2016) also suggest improving ecological validity by moving beyond key pressing paradigms to spoken responses, introducing two-person social interaction stimuli rather than one-person stimuli reacting towards the observer and moving away from 2D representations of stimuli into immersive 3D virtual reality scenarios.

In the present study, we saw different levels of emotion recognition accuracy across emotions in the full-body condition, which reflects what is seen in the emotion recognition literature (Atkinson, Dittrich et al. 2004, de Gelder and Van den Stock 2011, Ross, Polson et al. 2012). Although we were interested in how removing the hands and arms differentially affects emotion recognition in each emotion, having different levels of recognition as a baseline may interact with how the removal of information further influences subsequent recognition. It should also be noted, however, that the pattern of recognition accuracy we observed in our full-body condition was the same as the original validation study for this stimuli set (de Gelder and Van den Stock 2011).

In summary, we have demonstrated a potential key role played by the hands for emotion recognition from the body. Specifically, the form of the hands appear to be more important for emotion recognition of fearful and angry bodies compared with happy and sad bodies. This could be due to the 'action' of the hands being lost in the former stimuli, but further exploration of this assertion is needed. These results have important implications for the field of emotion recognition, as they demonstrate an important, and as yet relatively uninvestigated, diagnostic

feature of emotion recognition from the body. Finally, studies using whole-body stimuli for emotion recognition research should do so with some caution, as rather than emotion recognition being from ‘the body’ as a whole, accuracy is likely to vary with the various forms and positions of the hands.

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# S1 Supplementary Material

## Confusion Matrices

*Table S1. Percentage of responses according to emotion in each condition.*

Full Body		Response (%)			
Target		Happy	Sad	Fearful	Angry
	Happy	66.5	2.9	5.8	24.8
	Sad	1.5	96.3	1.3	0.9
	Fearful	10.7	1.5	83.0	4.8
	Angry	9.6	1.4	2.8	86.2
No Arms		Response (%)			
Target		Happy	Sad	Fearful	Angry
	Happy	68.8	1.4	7.9	21.9
	Sad	1.3	96.3	1.7	0.7
	Fearful	11.5	1.0	83.5	4.0
	Angry	10.3	1.8	4.2	83.6
No Hands		Response (%)			
Target		Happy	Sad	Fearful	Angry
	Happy	70.7	1.9	8.7	18.7
	Sad	0.8	95.5	2.4	1.3
	Fearful	17.1	3.5	66.1	13.4
	Angry	16.5	6.3	8.7	68.5
No Hands/Arms		Response (%)			
Target		Happy	Sad	Fearful	Angry
	Happy	54.3	16.4	12.4	16.9
	Sad	4.9	88.8	3.5	2.8
	Fearful	17.1	7.8	62.2	12.9
	Angry	19.4	13.3	7.6	59.8



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3 **Response Times**

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6 For each participant we computed the median response time for correct

7 responses for each condition (See Fig S1). We should note here that due to

8 the paradigm not being initially designed to gather RT data, responses were

9 only available for 63 of our 93 participants.

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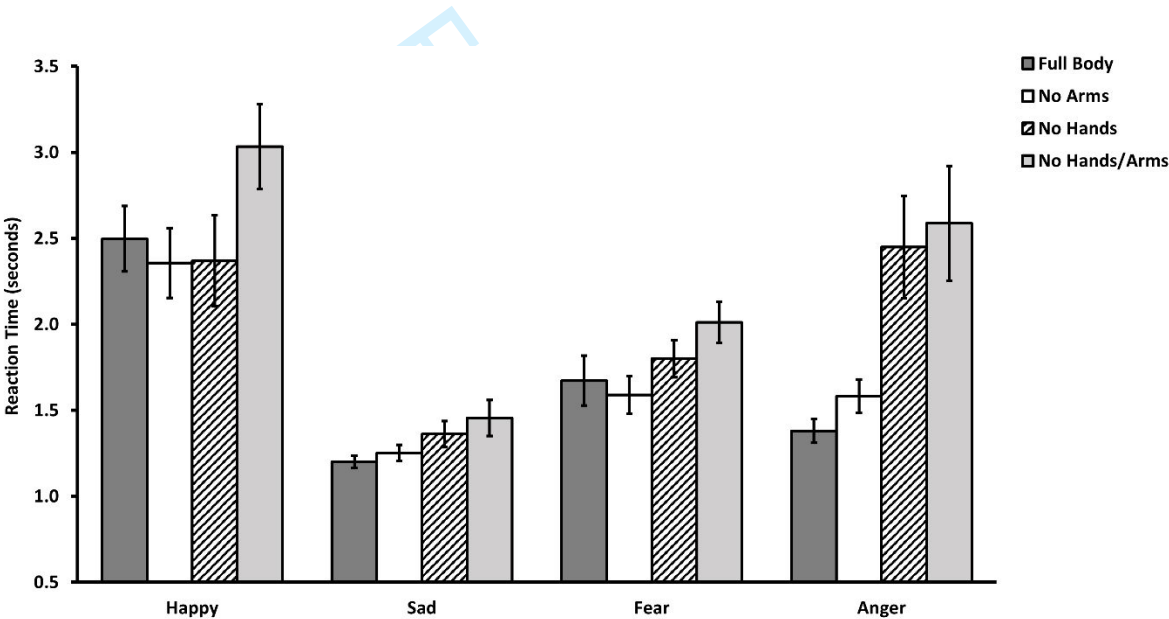
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41 **Figure S1. Average median response time (seconds) for correct responses for the four**

42 **stimuli conditions, Full Body, No Arms, No Hands and No Hands/Arms at each emotion**

43 **(Happy, Sad, Fear and Anger). Error bars represent SEM.**

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47 Median RTs for correct responses were entered into a 4x4 ANOVA with the

48 factors Emotion (Happy, Sad, Fearful, Angry) and Condition (Full Body, No

49 Arms, No Hands, No Hands/Arms).

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54 We found a main effect of Emotion (Happy:  $M=2.56$ ,  $SE=.18$ ; Sad:  $M=1.32$ ,

55  $SE=.05$ ; Fear:  $M=1.77$ ,  $SE=.11$ ; Anger:  $M=2.0$ ,  $SE=.14$ ;  $F(3,147)=27.23$ ,  $p<.001$ ,

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$\eta^2_p = .357$ ). Bonferroni corrected pairwise comparisons revealed this main effect to be driven by significant differences between RT in all emotions (all  $p < .001$ ) except Fear and Anger which showed no significant difference ( $p = .549$ ).

A main effect of Condition (Full Body:  $M = 1.69$ ,  $SE = .09$ ; No Arms:  $M = 1.69$ ,  $SE = .09$ ; No Hands:  $M = 2.00$ ,  $SE = .14$ ; No Hands/Arms:  $M = 2.27$ ,  $SE = .14$ ;  $F(3, 147) = 13.27$ ,  $p < .001$ ,  $\eta^2_p = .213$ ) was driven by significant differences between all conditions (all  $p < .001$ ) with the exception of Full Body and No Arms ( $p > .9$ ), and No Hands and No Hands/Arms ( $p = .296$ ) which showed no significant difference in RT.

These main effects are qualified by a significant Emotion  $\times$  Condition interaction ( $F(9, 441) = 3.72$ ,  $p < .001$ ,  $\eta^2_p = .071$ ). Post-hoc one-way ANOVAs of conditions across emotions found main effects of Condition under each Emotion with the exception of Sadness (Happy,  $F(3, 162) = 4.57$ ,  $p < .005$ ,  $\eta^2_p = .078$ ; Sad,  $F(3, 186) = 1.8$ ,  $p = .149$ ,  $\eta^2_p = .028$ ; Fear,  $F(3, 183) = 8.72$ ,  $p < .001$ ,  $\eta^2_p = .125$ ; Anger,  $F(3, 174) = 1.74$ ,  $p < .001$ ,  $\eta^2_p = .156$ )

Bonferroni corrected pairwise comparisons showed that for Happiness, the No Hands/Arms condition ( $M = 3.16$ ,  $SE = .28$ ) led to significantly longer RTs than No Hands ( $M = 2.40$ ,  $SE = .19$ ;  $p < .05$ ) and No Arms ( $M = 2.45$ ,  $SE = .25$ ;  $p < .05$ ) but not compared to Full Body ( $M = 2.56$ ,  $SE = .21$ ;  $p = .08$ ). There were no other significant differences between the other conditions (all  $p > .9$ ).

For Fear, we found that the No Hands/Arms condition ( $M = 2.03$ ,  $SE = .10$ ) again led to longer RTs compared to Full Body ( $M = 1.68$ ,  $SE = .12$ ;  $p < .05$ ) and No Arms ( $M = 1.63$ ,  $SE = .09$ ;  $p < .001$ ) but no significant difference in RTs compared to No

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Hands ( $M=1.86$ ,  $SE=.10$ ;  $p=.465$ ). We also found that the No Hands condition led to significantly longer RTs than the No Arms condition ( $p<.05$ ).

Similarly, for Anger, we found that No Hands/Arms ( $M=2.56$ ,  $SE=.29$ ); led to significantly longer RTs compared to Full Body ( $M=1.40$ ,  $SE=.06$ ;  $p<.001$ ) and No Arms ( $M=1.57$ ,  $SE=.08$ ;  $p<.005$ ) but not compared to No Hands ( $M=2.41$ ,  $SE=.255$ ;  $p>.9$ ). Interestingly, RTs in the No Hands condition were again significantly longer than the Full Body ( $p<.001$ ) and No Arms ( $p<.01$ ) conditions. No significant difference was found between the Full Body and No Arms conditions ( $p=.172$ ).